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(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) CO2 Recycle for a Gas-Fired Turbogenerator

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Notice: This application is as filed and may therefore contain an incomplete specification.

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# CARBON DIOXIDE RECYCLE FOR A GAS-FIRED TURBOGENERATOR


## ABSTRACT OF THE DISCLOSURE

The present invention relates to a process for the production of carbon dioxide and electrical power. It combines closed cycle gas and steam turbine power generation with the production of a substantially pure carbon dioxide product with a minimal effect on the efficiency of electrical power generation.

# CARBON DIOXIDE RECYCLE FOR A GAS-FIRED TURBOGENERATOR

## Scope of the Invention

The present invention relates to a process for the production of carbon dioxide and electrical power. It combines closed cycle gas and steam turbine power generation with the production of a substantially pure carbon dioxide product with a minimal effect on the efficiency of electrical power generation.

## Background of the Invention

One of the drawbacks in the production of electricity by burning carbonaceous fuels is the generation of large quantities of waste gas emissions which are subsequently released to the atmosphere. In the past, in the absence of pretreating the fuel and oxidant and post-treatment of the exhaust gases, substantial quantities of waste and by-product gases have been released to the atmosphere as pollution.

The principal products of burning carbonaceous fuels in electrical power plants are carbon dioxide and water when fuel is oxidized under ideal conditions. However, non-ideal conditions occur in practice often with impure fuels containing sulphur and other contaminants and with oxidants containing atmospheric nitrogen. Combustion of these impure gases results in an assortment of combustion gases in the stack, primarily comprising unreacted atmospheric nitrogen and dilute concentrations of carbon dioxide

but also including oxides of nitrogen and sulphur. These last three gases all contribute to air pollution and its associated impact on human health. There is, therefore, a great need to provide a means of reducing polluting gases emitted from power generating plants in addition to recovering any desirable waste products. Fuel burning power plants provide a plentiful source of otherwise polluting carbon dioxide and, hence, the recovery of high purity carbon dioxide in large quantities is desirable for other uses, for example in enhanced oil recovery.

The existing technologies for the extraction of carbon dioxide include absorption stripping, molecular sieves, refrigeration and others. As the concentration of carbon dioxide in the exhaust gases of an electrical power generating plant is typically low, diluted by other gases participating in the combustion process the extraction of $CO_2$ from a dilute mixture using the above technologies is inefficient, leading to a lower efficiency of the power generating plant and/or a substantial increase in operating costs.

From literature and our knowledge of conventional procedures, there is no suggestion of producing high purity carbon dioxide in combination with an efficient electrical power producing plant utilizing both steam and gas turbine power generation.

Increasing the efficiency of carbon dioxide extraction can be achieved by increasing the concentration of carbon dioxide in the exhaust gases. The Argonne National Laboratory (Argonne, Illinois) has proposed combusting a hydrocarbon fuel in a conventional boiler using a stream of oxygen and recycled flue gas instead of atmospheric air. In this

process, atmospheric nitrogen and other trace gases are separated from the atmospheric oxygen prior to combustion, and are replaced by recycled flue gas. These recycled gases, having been through the combustion process have an increased carbon dioxide concentration.

US Patent 4,434,613 describes producing CO2 from a closed cycle gas turbine but the principle use of the turbine is as a chemical processor and not for power generation. Similarly, US Patent 3,866,411 describes recycling flue gas through a turbine but this process is for increasing the mole ratio in the flue gas stream. It does not produce high quality CO2 gas and does not use steam from the gas generator or waste heat to provide electric power.

Another problem identified with closed cycle power generation is stalling the compressor/turbine when higher relative molecular weight gases are used. No prior art has identified the solution to using high relative molecular weight gases in a closed cycle compressor/turbine. The high relative molecular weight of carbon dioxide at 44 compared with the average molecular weight of air at 29 entering the compressor/turbine leads to stalling.

## Summary of the Invention

The present invention relates to an improvement in this process in the form of an integrated coal gasification combined cycle plant utilizing both gas and steam turbines to produce electricity in a two stage process with minimal effect on overall plant efficiency.

The present invention relates to a process to produce carbon dioxide and power comprising the steps of:

a) introducing oxygen into a proportion of an exhaust gas stream of a gas turbine to create an exhaust/oxygen gas mixture;

b) introducing a proportion of the exhaust/oxygen gas mixture into the compressor of the gas turbine;

c) premixing a fuel gas and the remaining proportion of the exhaust/oxygen gas stream to create a fuel/exhaust/oxygen gas mixture;

d) introducing the fuel/exhaust/oxygen gas mixture into the combustion chamber of the gas turbine whereby it undergoes combustion to drive the gas turbine;

e) introducing the exhaust gas stream of the gas turbine into a heat recovery steam generator whereby heat is recovered to produce steam;

f) introducing the heat recovery steam generator steam into a steam turbine;

g) recovery of the remaining proportion of the exhaust gas stream as a product stream substantially comprising carbon dioxide.

Furthermore, the invention reduces stalling problems in the compressor/turbine due to the high relative molecular weight of exhaust gases entering the compressor/turbine. Low grade heat in the recycle gas stream is used to evaporate water into the gas stream in the saturator vessel in order to provide humidification.

The present invention also provides a means of reducing the oxygen requirement of a combustor by

using fuel obtained from a gasifier in a partially oxidized form.

The invention also provides a means of cooling the combustor by pre-mixing the exhaust/oxygen mixture with the fuel gas. In a gas turbine, air is typically passed over the outer surface of the combustor in order to prevent material overheating. In the present invention, as is the case with the working fluid in the turbine stage, this cooling mass flow is maintained by replacing the nitrogen in air with recycled exhaust gases.

The invention is illustrated by way of example in the accompanying drawings in which:

FIGURE 1 is a schematic illustration of a conventional gas turbine cycle;

FIGURE 2 is a schematic general illustration of an oxygen fired gas turbine cycle according to the invention; and

FIGURE 3 is a schematic diagram of an integrated coal gasification plant according to the invention.

<u>General Description</u>

In a conventional gas turbine, as shown schematically in Figure 1, air provides the oxygen necessary for combustion, and the products of combustion include a large amount of nitrogen.

The oxygen fired gas turbine cycle according to the invention is shown schematically in Figure 2. The basis of this cycle is as follows:

At point 1 air has been separated to provide oxygen. The nitrogen from the air is vented.

At point 2 the oxygen is mixed with recycled flue gas, composed primarily of carbon dioxide. Total mass flow is maintained with the nitrogen of the air now replaced by carbon dioxide.

The mixture of oxygen and recycled flue gas then goes to the combustion chamber of the gas turbine point 3.

The combustion gases are expanded through the gas turbine to point 4. The products of combustion are now carbon dioxide and water with no nitrogen in the exhaust.

A portion of the turbine exhaust is extracted at point 5 providing a stream of nearly pure carbon dioxide.

While the remainder of the exhaust gas is cooled and recycled, point 6.

Detailed Description of a Preferred Embodiment

Figure 3 shows a schematic diagram of an integrated coal gasification plant 5 according to the present invention. Fuel gas 10 is premixed with a proportion of a stream of compressed and pre-heated oxygenated recycle gas 14 before entering a combustor 12 where combustion of the fuel gas 10 occurs. The hot combustion gases 20 enter a gas turbine 16 operatively connected to a conventional power generating means 18. The remaining proportion of the compressed oxygenated recycle gas 14 is fed directly to the gas turbine 16. The exhausted gas turbine gases 22 are fed into a heat recovery steam generator 24.

Within the heat recovery steam generator 24, the exhausted gas turbine gases 22 are cooled, their heat extracted to produce steam 26 for use in a steam

turbine 28. Upon exiting the heat recovery steam generator 24, the cooled exhaust gases 22 are split into two streams, a recovery stream 30 of carbon dioxide and a recycle stream 32 leading to a gas turbine compressor 34, thus completing the closed gas turbine cycle. A saturator 36 is positioned prior to recycle stream 32 oxygenation for further cooling and humidification. The humidification serves to lower the average molecular weight of oxygenated gas 14 entering the compressor 34.

Steam 26, downstream of the steam turbine 28, is cooled in a condenser 38 to form water 40. The water stream 40 is subsequently split into two streams 42 and 44. Water stream 42 is for use in the fuel processing stages and water stream 44 is returned to the heat recovery steam generator 24 for steam production.

Pre-heating of the compressed oxygenated gas 14 occurs in the heat recovery steam generator 24.

The carbon dioxide recovery stream 30 is optionally dehumidified using condensing coils and further moisture can be removed using glycol dehydration. Moisture removed can be used in the humidification of the recycle stream 32 in the saturator 36. Any oxygen in the recycle stream 30 can be removed through oxygen removal processes in which case it can be returned to the combustor 12, or by catalytic combustion in which case additional carbon dioxide can be produced.

Fuel processing in the integrated coal gasification combined cycle plant is performed to produce high quality fuel for use in the combustor 12. Atmospheric air 46 enters a compressor 48 driven by an electrical motor 50. The compressed air 52 enters an

atmospheric separator unit 54 which separates the gas into primarily nitrogen 56 and oxygen streams 58. The nitrogen stream 58 is released and, The oxygen stream 58 is compressed in a second compressor 60 driven by a second motor 62. The compressed oxygen stream 64 is split into two streams for use in a gasifier unit 68 and for oxygenation of the recycle gas stream 32. Also entering the gasifier 68 is pulverized coal 70 and water stream 42. The gasifier 68 produces syn gas 72 and steam for use in the heat recovery steam generator 24. The syn gas 72 is cooled in a gas cooler 74 with additional steam produced for use in the heat recovery steam generator 24. Slag 78 is removed from the syn gas 72 by a slag removal unit 76 which is recycled to the gasifier 68. The syn gas 72 is further cleaned with sulphur 80 and tail gas 82 removal in a gas cleanup unit 84. In the illustrated case, "tail gas" refers to the gases remaining after the acid gases, which are removed from the syn gas stream, have been treated to recover elemental sulfur. These tail gases would typically be recycled and burned in the gas turbine.

Optimization of the system maximizes carbon dioxide production with the efficient generation of electricity.

While the invention has been described in connection with a specific embodiment thereof and in a specific use, various modifications thereof will occur to those skilled in the art without departing from the spirit and scope of the invention as set forth in the appended claims.

The terms and expressions which have been employed in this specification are used as terms of description and not of limitations, and there is no intention in

the use of such terms and expressions to exclude any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A process for producing carbon dioxide and power comprising the steps of:

a) introducing oxygen into a proportion of an exhaust gas stream of a gas turbine to create an exhaust/oxygen gas mixture;

b) introducing a proportion of the exhaust/oxygen gas mixture into the compressor of the gas turbine;

c) premixing a fuel gas and the remaining proportion of the exhaust/oxygen gas stream to create a fuel/exhaust/oxygen gas mixture;

d) introducing the fuel/exhaust/oxygen gas mixture into the combustion chamber of the gas turbine whereby it undergoes combustion to drive the gas turbine;

e) introducing the exhaust gas stream of the gas turbine into a heat recovery steam generator whereby heat is recovered to produce heat recovery steam generator steam;

f) introducing the heat recovery steam generator steam into a steam turbine;

g) recovery of the remaining proportion of the exhaust gas stream as a product stream substantially comprising carbon dioxide.

2. The process as described in claim 1 further comprising:

a) a saturator to saturate the proportion of the

exhaust gas stream leading to the gas turbine compressor with water.

3. The process as described in claim 2 further comprising:

a) a condenser downstream of the steam turbine to convert heat recovery steam generator steam to water and;

b) reintroducing the water to the heat recovery steam generator for recycling.

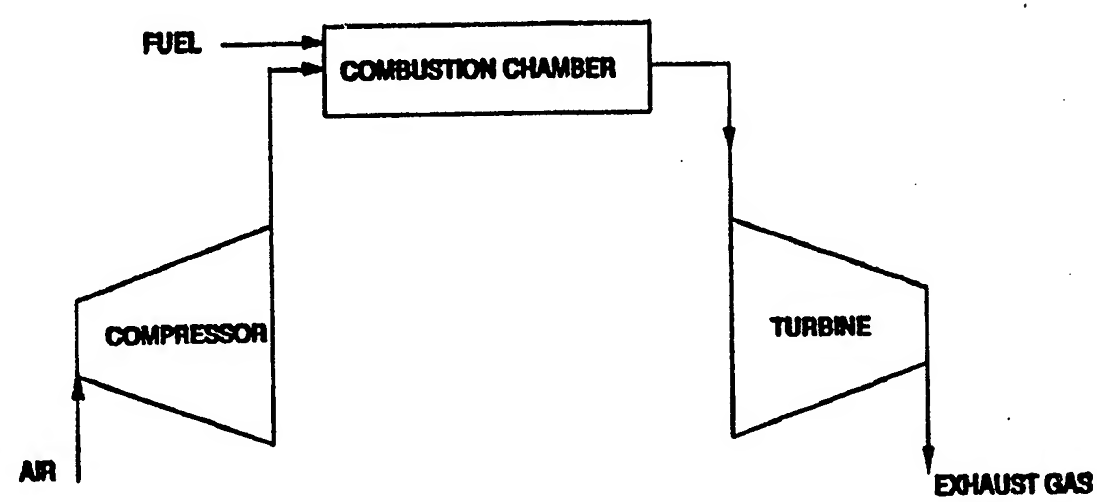
4. The process as described in claim 1 further comprising:

a) introducing additional steam to the heat recovery steam generator from other plant processes for use in the heat recovery steam generator.

5. The process as described in claim 1 whereby the fuel gas is partially oxidized syn gas.

6. The process as described in claim 1 whereby the proportion of the exhaust/oxygen gas mixture being fed into the combustor is preheated.

GAS TURBINE




Fig·1·

PRIOR ART

Gowling, Strathy & Henderson

GAS TURBINE EXHAUST GAS RECYCLE

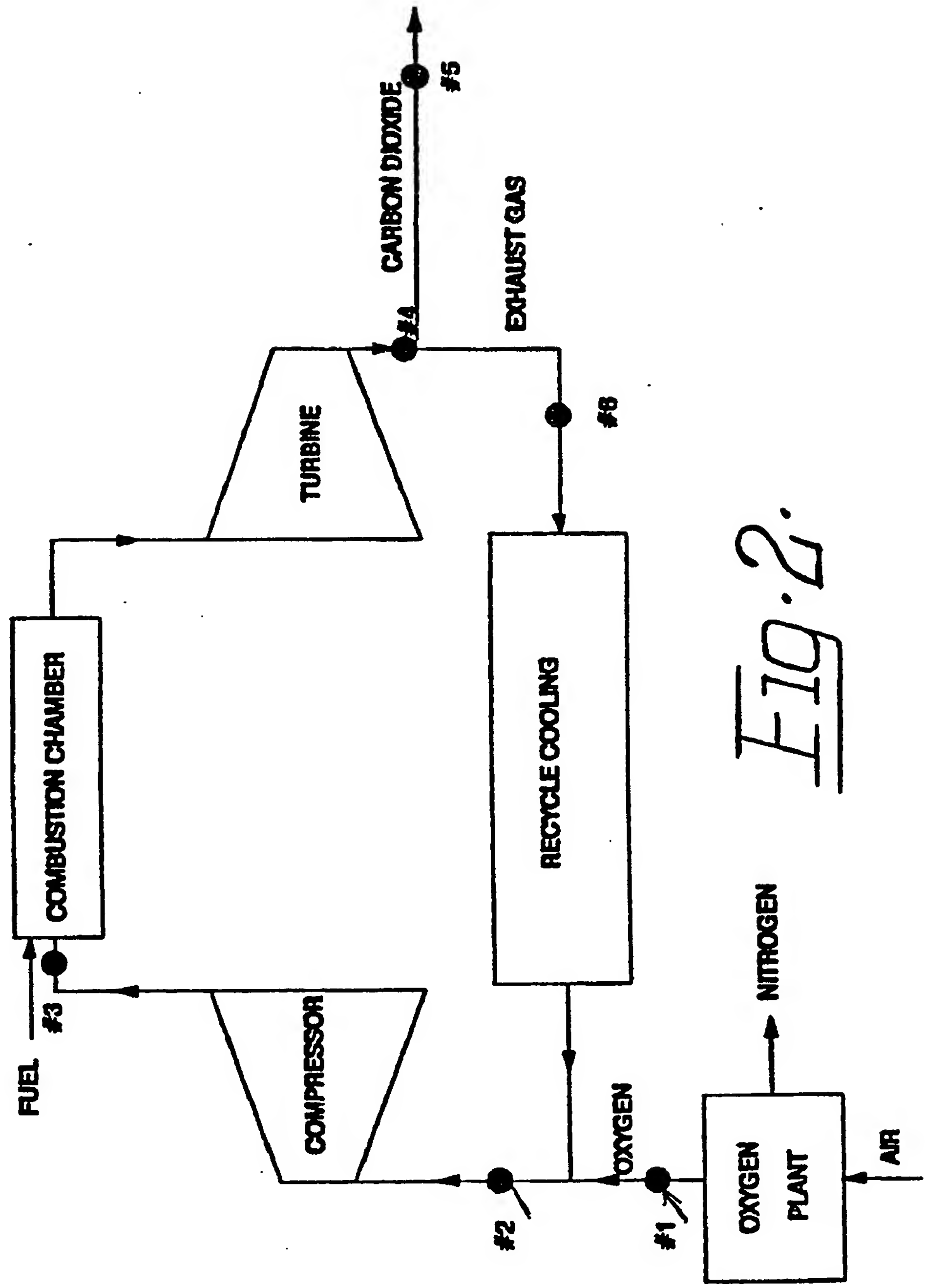



Fig. 2.

Gowling, Strathy & Henderson

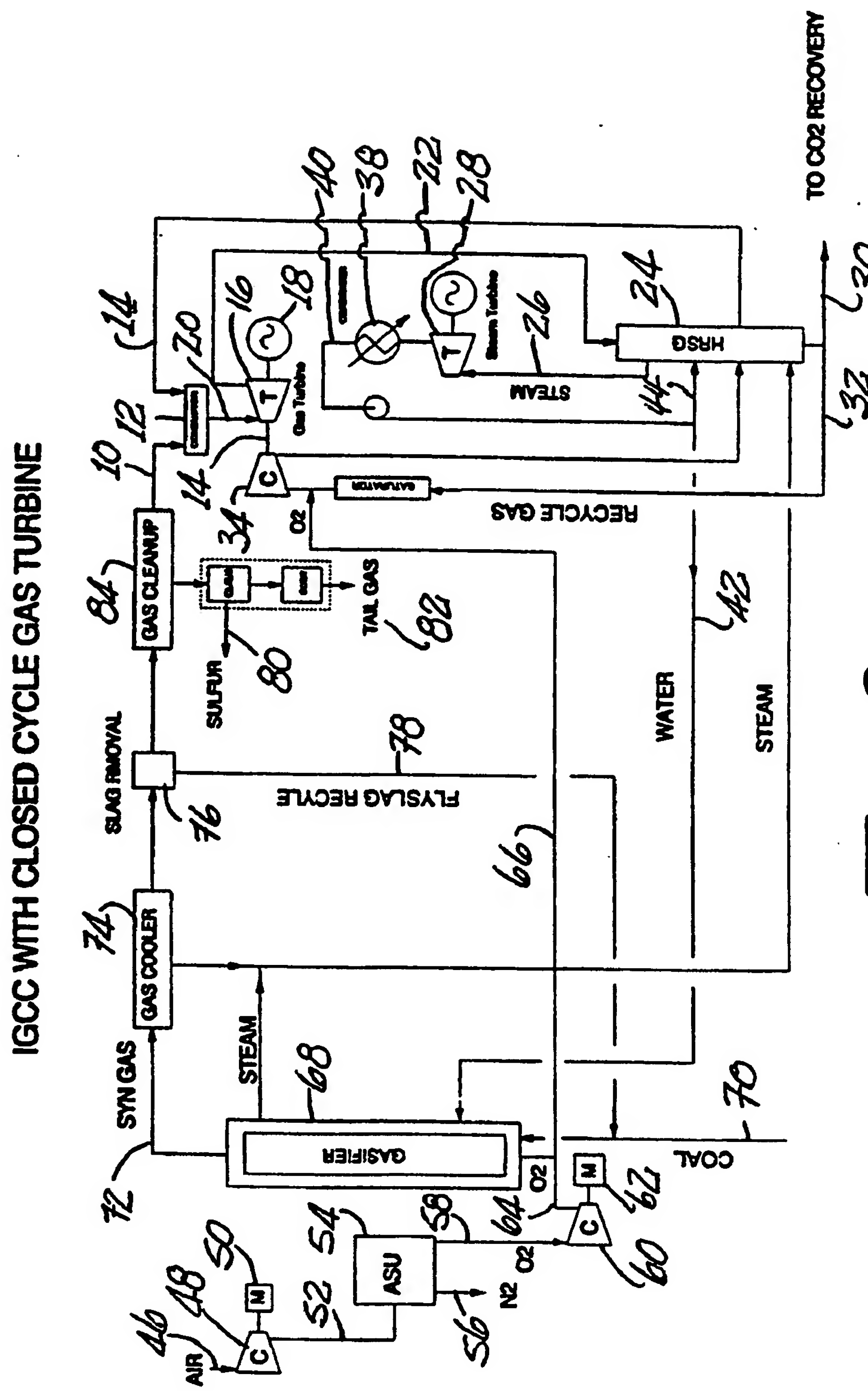



Fig. 3.

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